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INTRODUCTION

The bumphead parrotfish (*Bolbometopon muricatum*) is a large, benthic grazing fish found on coral reefs of the Indo-West Pacific. Bumphead parrotfish do not occur within state waters of the United State (U.S.), but occur in certain U.S. jurisdictions such as the territories of Guam, Northern Mariana Islands, and American Samoa; and in the U.S. Pacific Remote Island Areas (PRIAs) of Palmyra, Jarvis Island, and Wake Island (Mundy, et al. 2011). The bumphead parrotfish is thought to be a potential keystone species and could play an important role in ecological processes (Bellwood et al., 2003).

This species is considered a "Species of Concern" (SOC) by the National Marine Fisheries Service (NMFS) due to apparent overharvesting and declining adult abundance in portions of its range. In September 2011, a status review was conducted to determine if a listing under the Endangered Species Act (ESA) was warranted (Kobayashi et al., 2011). In November 2012, NMFS concluded "the bumphead parrotfish is not currently in danger of extinction throughout all or a significant portion of its range, and not likely to become so within the foreseeable future (77 *FR* 216; Nov 7, 2012)" resulting in a negative finding on the petition to list under the ESA. However, the bumphead parrotfish is categorized as "Vulnerable" under the International Union for Conservation of Nature (Chan et al., 2012) and juvenile habitat loss and degradation was identified as a severe threat to this species (77 *FR* 216; Nov 7, 2012, Kobayashi et al., 2011).

Although all aspects of its life history remain important, the early life history is of particular importance for this species (Aswani & Hamilton, 2004; Hamilton et al., 2008; Bellwood & Choat, 2011). Some locations are oddly devoid of young fish, yet these same areas maintain large numbers of adult fish. This particular situation is observed on the Great Barrier Reef (GBR) where juveniles (< 35 cm) consist of only 0.6% of the total bumphead parrotfish population compared to 20.2 − 40.2% in other parrotfish species surveyed (Bellwood & Choat, 2011). This does not appear to be a consequence of incomplete surveying techniques, but rather, adult fish are migrating to these areas from other regions where settlement or juvenile survivorship is presumably more successful (Bellwood & Choat, 2011). This highly skewed size demographic experienced in the GBR suggests certain high-density refuge locations may not be self-maintaining and may rely on areas outside the scope of protection for recruitment and on suitable corridors of movement for adults. This unconventional feature in its population dynamics may be an important factor for a species of such concern for conservation.

Among U.S. jurisdictions where bumphead parrotfish are found, Wake Island represents the highest density of adults in U.S. waters. Wake Island is a coral atoll made up of three islands surrounding a central lagoon. It is located halfway between Hawaii and Guam at 19°18' N and 166°38' E. The U.S. Army manages all on-island operations. It is primarily used as a refueling and emergency-landing site for trans-Pacific flights. Classified activities conducted by the Military Defense Agency (MDA) occur here as well.

The abundance of adult fish at Wake Island may be indicative of this unique environment allowing relatively undisturbed populations of this species to flourish. Preliminary estimates of larval transport and connectivity indicate that the oceanographically isolated Wake Island would have to be primarily self-seeding (Kobayashi, unpublished data), meaning juvenile and adult bumphead

populations are likely residing in close proximity, but this has not been confirmed in any published or unpublished research findings. A key question therefore is, does Wake Island support a full demographic population or is it dependent on adults moving in from other regions or episodic recruitment events. While adults have been observed spawning at Wake Island (Munoz et al., 2012), it is not clear if there is successful or persistent recruitment of these resultant propagules back to Wake Island.

Numerous studies of bumphead parrotfish have shown juveniles appear to prefer shallow (0–10 m), low-energy areas such as lagoons, seagrass beds, mangroves, and areas with plumose, fleshy algae (*Halimeda* spp., *Dictoyota* spp., *Sargassum* spp.) or patch coral formations consisting of *Turbinaria* spp. and *Acropora* spp. This information is based on studies in the Solomon Islands (Aswani & Hamilton, 2004; Hamilton, 2004) and in the Cocos-Keeling Islands in the Indian Ocean (Kobayashi et al., 2011). The most protected portions of the inner lagoon at Cocos-Keeling were found to harbor the highest density of juvenile bumphead parrotfish. The interior lagoon at Wake Island has a similar geomorphology (although lacking mangroves) to Cocos-Keeling, potentially allowing for high juvenile bumphead parrotfish presence. To our knowledge, this probable critical habitat has not been carefully inventoried for biota or specifically surveyed for juvenile bumphead parrotfish. The Coral Reef Ecosystem Division of the Pacific Islands Fisheries Science Center has conducted Rapid Ecological Assessment surveys at Wake Atoll in 2003, 2005, 2007, 2009, and 2011 (http://www.pifsc.noaa.gov/cred/), but the lagoon has been relatively unexplored.

A team of 4 researchers traveled to Wake to conduct snorkel surveys in the lagoon with intentions of identifying and characterizing juvenile habitat and nursery grounds preferred by juvenile *Bolbometopon muricatum*. The survey results were intended to confirm or reject bumphead parrotfish presence in the lagoon and provide a better understanding of the dynamics of settlement and recruitment of this species.

In addition to the bumphead parrotfish survey, water samples were collected, carbonate chemistry dynamics were analyzed, and tissue samples of reef fishes and invertebrates were opportunistically collected.

METHODOLOGY

In collaboration with the United States Air Force (USAF), Wake Island command, Wake Island Base Operations, and Chugach Federal Solutions, Inc., a 4-member scientific team conducted a 12-day survey of the lagoon at Wake Island. Two Joint Institute for Marine and Atmospheric Research (JIMAR) employees, one Hawaii Pacific University (HPU) professor, and one University of Hawaii (UH) professor departed Hickam Air Force Base via Air Mobility Command on June 12, 2013, on a C-17 rotator flight; they returned to Honolulu on June 26, 2013. Two participants were NOAA Scientific Divers and 2 met the requirements for swimming and snorkeling under NOAA guidelines and supervision.

Each morning, the crew snorkeled a predetermined region, covering the largest area possible. When bumpheads were located, a survey design mimicking the methodologies described in Bellwood & Choat 2011 (5-m-wide 10 or 20 min swim transects with two divers surveying simultaneously: one for fishes less than 10 cm and the other for fishes greater than 10 cm) would be utilized. Personal snorkel gear was used during operations and a 72-Hertz Garmin® GPS was towed behind the 2 JIMAR participants during each survey to document the tracks snorkeled. To cover more area and explore various depth strata and bottom types, the team split into two groups when applicable. Snorkeling operations were planned around high tide. Time constraints forced survey operations to skip sections of the lagoon consisting primarily of sandy bottom. Thirteen snorkel surveys were conducted in total, with 6 surveys in waters around Peale Island (2 were conducted with and without a GPS) and 7 surveys in waters around Wake Island (Figs. 1−4).

Two sites were selected to collect water samples from, a back-reef site on the north side of Wake Island and an inner lagoon site (Fig. 5). Water sampling occurred regularly at sunrise and sunset and periodically at mid-day (~ noon); temperature and salinity measurements were also taken at each site. For reference, ground water samples were collected from two wells at the island's water plant. Analysis of carbon parameters (total alkalinity, pH, total dissolved inorganic carbon) occurred post trip.

Fin clips of reef fishes, pieces of coral, and invertebrate appendages were opportunistically collected during the excursion for later analysis in the laboratory at the Hawaii Institute of Marine Biology (HIMB) (Table1). These samples are to be used in a pan-Pacific phylogenetic study.

A grounding event occurred while the team was on island June 15, 2013. The re-supply barge, Chamorro, ran aground on the reef surrounding the entrance to the marina. Fish and Wildlife Services (FWS) requested the team to identify the extent of the damages and assess the severity of the situation.

Island personnel escorted the team to the grounding site (access to the channel of the marina was prohibited without supervision). Video and GPS points of the area of impact were recorded; the size and extent of the injury footprint was measured by taking the length and width of the impact. The team identified and repositioned displaced coral (1 small, intact, displaced *Acropora sp.* colony was wedged back into place). The majority of the grounding site was composed of Pleistocene and Holocene (dead) reef. The absence of many live corals on initial appraisal showed the extent of the damage as minimal.

RESULTS AND DISCUSSION

Juvenile bumphead parrotfish were not found during the 13 snorkel surveys on Wake Island (Figs. 1−4) and only 5 adult bumphead parrotfish were spotted the entire trip (3 in the lagoon, 2 at the Stoner wreckage). The scarcity of adults was expected considering they are usually found on the outer reefs in deeper water; however, we were not allowed to survey the areas around Wilkes island, where bumpheads have historically been found in highest abundances (Munoz et al., 2012). The lack of juveniles is surprising, but it is premature to conclude that juvenile bumphead parrotfish are completely devoid from the lagoon and surrounding waters since much of the lagoonal habitat has yet to be explored.

Prior to departure, a variety of factors prevented the team from conducting the survey they envisioned; much of the lagoon and back-reef was inaccessible during their stay due to military operations, the lead scientist of the project was unable to participate due to federal government travel restrictions, visibility and potential habitat within the lagoon was limited, the rules and regulations imposed by the USAF prevented the team from accessing certain regions of the lagoon, SCUBA surveys weren't possible due to lack of appropriate equipment, and arranging for travel to Wake was far more challenging than expected. These issues are described in more detail below; recognizing and addressing such logistical issues are key to planning subsequent trips to this and other remote locales.

All of Wilkes Island and surrounding waters were off limits in June because of a coinciding visit by the MDA (Figs. 1, 4). The MDA was conducting confidential, military-related operations, thereby limiting access to a large portion of the island. The USAF was pre-occupied with MDA activities during the bumphead parrotfish survey, further stretching already limited resources. The secretive nature of military operations did not allow for many of these restrictions to become known until the team was already on-island.

Federal travel restrictions prevented the lead scientist who initiated the bumphead parrotfish work and procured funds for fieldwork operations from participating; his participation would have significantly enhanced the team's surveying capabilities.

The lagoon was very turbid, making 5-m transects impossible. Visibility was poor, rarely exceeding 1 m. When possible, reconnaissance surveys were planned in close proximity to high tide. The lagoon was either too shallow or visibility too poor at low tide. The majority of the lagoon was of sandy substrate contributing to suspended particles and visibility constraints. Structure, in the form of patch and aggregate reef, was minimal in the areas of the lagoon accessible to the team. Initially, surveys were intended to stay within the confines of the lagoon, but due to the lack of diversity and visibility issues, the extent of the survey was expanded to include some portions of the back-reef (Figs. 1−3).

Devising a statistically robust survey prior to departure was difficult, little was known about the conditions within the lagoon. Prior to departure, the team planned to follow Bellwood and Choat's (2011) survey methodologies, but when limitations in visibility did not permit this, formulating an alternative survey design was challenging.

USAF regulations restrict access to certain sections of the lagoon (near the airport) and all of the back-reef and fore-reef. These restrictions are in place to ensure the safety of Wake's visitors and residents. Due to its remoteness, medical assistance is difficult to obtain, which is why adhering to the safety protocols in place is of such extreme importance. The USAF is very protective of the few recreational activities available to them (snorkeling and diving being a favorite pastime); if an accident were to occur, these privileges could be revoked, which is why it took much deliberation to get the USAF to allow the team to snorkel certain portions of the back-reef along Wake and Peale. Visibility on the back-reef was relatively good most days (~ 3−6 m), but conditions did not resemble habitat presumed ideal for juvenile bumphead parrotfish.

The back reef was exceptionally high energy with an east-to-west cross-shore current driven by wind and waves. Juvenile bumphead parrotfish prefer shallow, protected, low-energy areas abundant in encrusting and fleshy algae, seagrass, or mangroves (Bellwood & Choat, 2011; Aswani & Hamilton, 2004), which could explain their absence from the back-reef. The following juvenile parrotfish species were, however, observed in the back-reef: *Chlorurus sordidus, Chlorurus frontalis, Scarus psitticus, Chlorurus microrhinos, Scarus altipinnis*, and *Scarus forsteni*.

The portions of the lagoon reachable by shore were too shallow (0–1.5 m) to conduct diving operations. The team intended to dive deeper depths found in the center of the lagoon using kayaks provided by Chugach to reach potential dive sites. Unfortunately, the one-man kayaks on-island were not appropriate for this, it would have taken far too much effort to travel to potential survey sites with the currents, wind, and wave chop present in the lagoon. Some regions of the lagoon not accessible by foot or by swimming were left unexplored due to lack of suitable support craft to transport the team (Fig. 1).

Plans to go to Wake Island to conduct a juvenile bumphead parrotfish abundance survey were initiated in 2011. Originally, the survey was to be conducted over a 2-week period anytime between August−October when water temperature would be at its warmest. If the timing of logistical considerations did not allow for deployment during the warm period, then an alternative excursion coinciding with the cool period (February−April) would occur. These time periods were chosen based solely on environmental considerations since, at that time, little was known about spawning seasonality or timing of recruitment. Numerous complications did not allow for travel to Wake during either of these periods, and the trip occurred June 12−June 26, 2013. June was not an ideal month for the survey to occur based on preliminary and anecdotal evidence of adult spawning seasonality, but the trip had been postponed several times since its fruition. Additionally, it was unknown when another opportunity would arise to visit this logistically challenging location; therefore, the decision to proceed with the trip was made.

Preliminary carbonate chemistry data collected from back-reef and inner lagoon sites over 4 and 1.5 diel cycles, respectively, showed an unexpected variability (4−8°C) in temperature. Significant variation in salinity was also recorded at both sites. Lower salinity was experienced near the seafloor at the back-reef site; which could be an indication of potential groundwater seepage. The opposite occurred at the inner lagoon site, a higher salinity was experienced near

the seafloor, which could suggest lagoon water masses were not well mixed. The pH and total alkalinity of collected water samples will be measured and processed at the HPU Carbonate Chemistry Laboratory in Makapu'u as time permits and resources allow. Additional information regarding the carbonate chemistry work conducted at Wake Island is available from Dr. Samuel Kahng at HPU.

The number of specimens collected for an ongoing pan-Pacific phylogenetic study can be found in Table 1. Additional information regarding the sampling conducted at Wake Island and results from this genetics study is available from Dr. Stephen Karl at UH.

Although the team was unsuccessful locating juvenile bumphead parrotfish during the 13 snorkel surveys conducted, the team was able to identify the resources available on-island, determine the obstacles involved in conducting a survey in such a remote locale, investigate portions of the lagoon and back-reef, as well as make valuable contacts with the USAF and Wake residents. This information and experience will be helpful towards follow-up trips.

A return trip(s) will be necessary to adequately survey the lagoon for presence of juvenile bumphead parrotfish (*Bolbometopon muricatum*), to clearly establish the demographic pattern for this population, and to determine if the GBR experience (limited recruitment) is occurring at Wake Island. Using information gathered on this initial survey, participation of an individual able to systematically and spatially plan areas to target based on habitat will be critical for future trips. Ensuring the excursion does not coincide with military operations will also greatly increase the areas available to survey.

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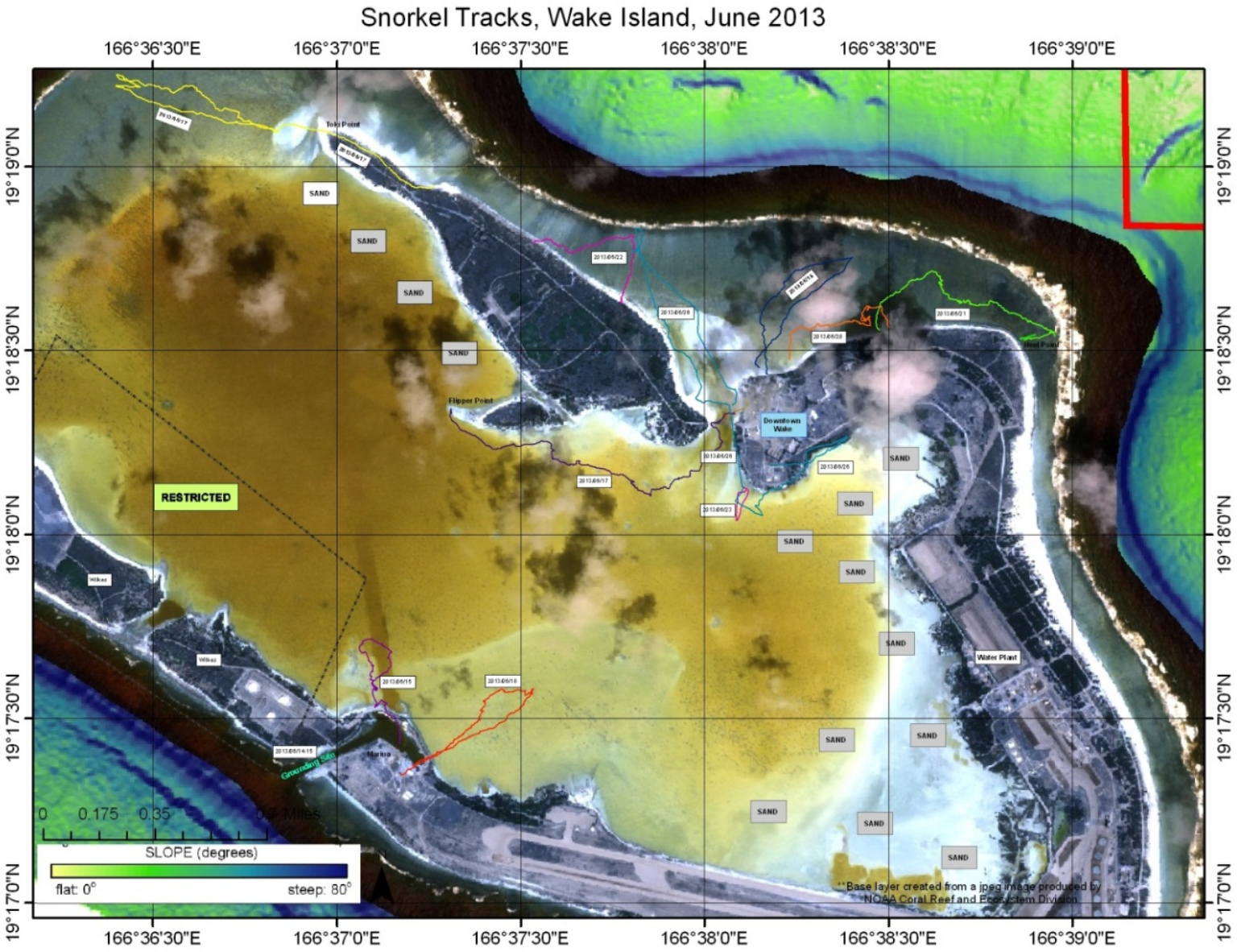

Figure 1.--Map of snorkeling operations at Wake Island, 13 total snorkel surveys were conducted. Four around Peale Island (2 were not tracked using a GPS unit), 5 around Wake Island near Downtown, and 2 on southern portion of Wake across from the marina.

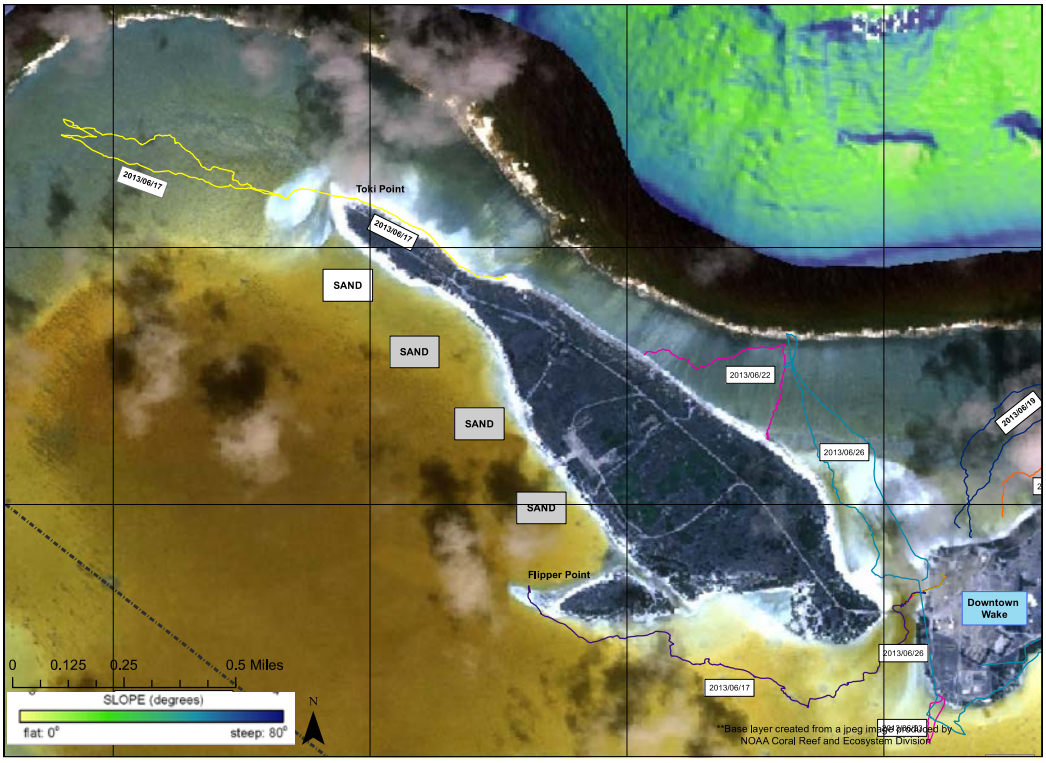

Figure 2.--Magnified map of Wake Island, showing the 4 snorkel tracks recorded with a handheld GPS device around Peale.

Snorkel Tracks, Wake Island, June 2013

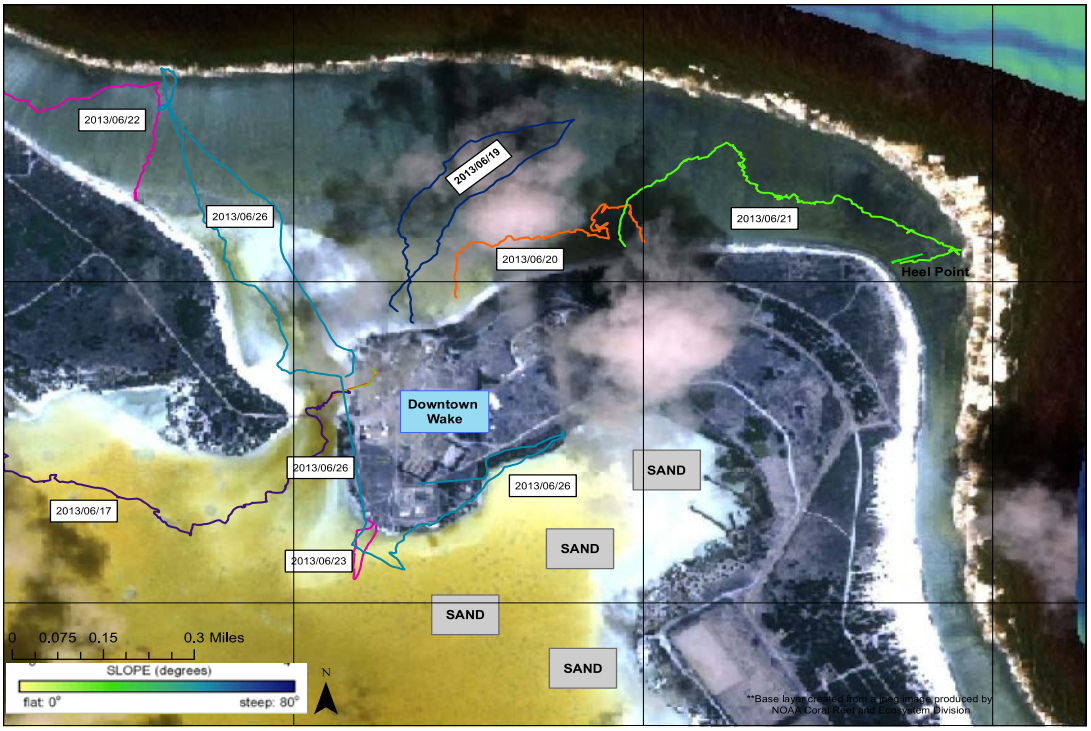

Figure 3.--Magnified map of Wake Island, showing the 4 snorkel tracks recorded with a handheld GPS device around Downtown Wake.

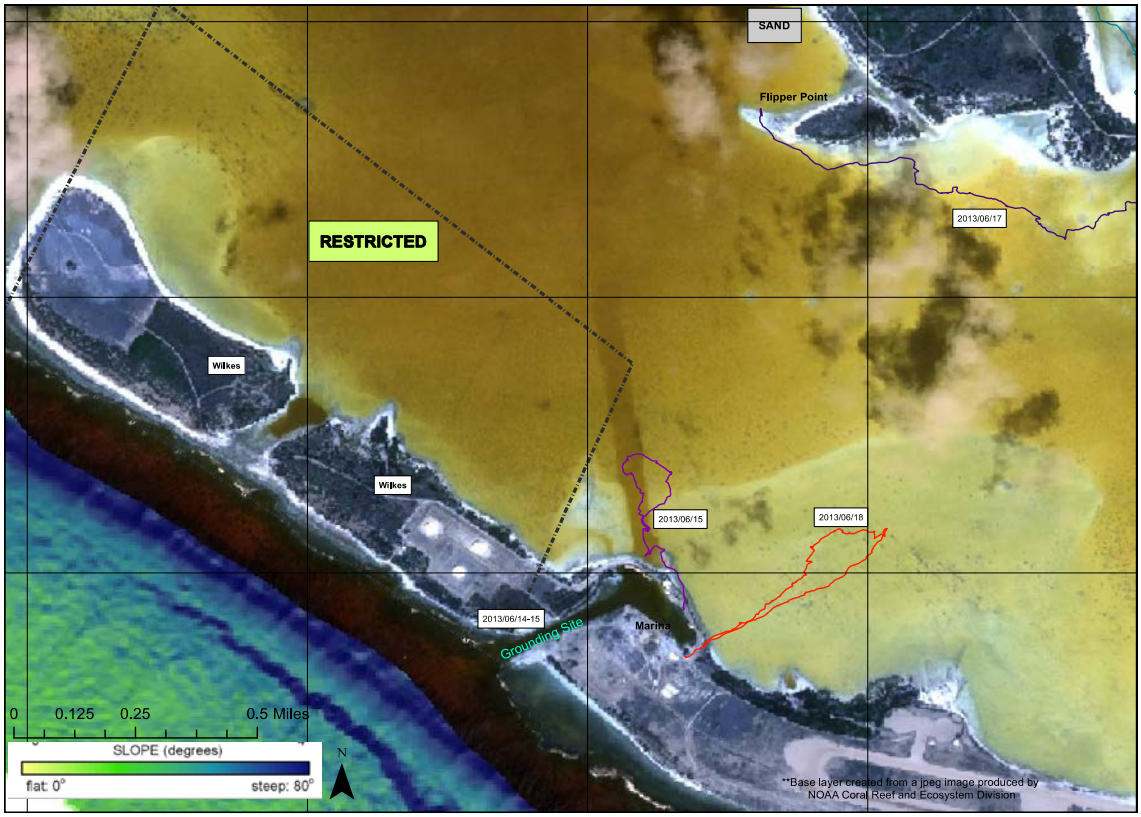

Figure 4.--Magnified map of Wake Island, showing the 4 snorkel tracks recorded with a handheld GPS device around Wilkes.

Figure 5.--Location of water sampling sites for carbonate chemistry baseline analysis.

Table 1.--Table of species collected and number of specimens collected from each species during Wake Island bumphead parrotfish survey; all specimens were collected by UH.

Scientific Name	Common Name	Type of Tissue Collected	Number Collected
Pocillopora damicornis	Lace Coral	Nubbin 3cm^2	1
Acropora cytherea	Table Coral	Nubbin 3cm^2	8
Acropora spp.	Table Coral	Nubbin 3cm^2	31
Linckia multifora	Spotted Sea Star	Arm Segment	80
Panulirus penicillatus	Tufted Spiny Lobster	Antenna	16
Echinometra mathaei	Oblong Urchin	Spine	62
Holothuria atra	Black Sea Cucumber	Skin	65
Centropyge flavissima	Lemonpeel Angelfish	Fin Clip	8
Mulloidichthys flavolineatus	Yellow Line Goatfish	Fin Clip	44